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PICATINNY ARSENAL TECHNICAL REPORT 3098

DETONATION OF A CYLINDER OF HIGH EXPLOSIVE CONTAINING AN AXIAL CORE OF PYROTECHNIC COMPOSITION

J. HERSHKOWITZ

E. DALRYMPLE

D. DORFMAN

AUGUST 1963

PICATINNY ARSENAL
DOVER, NEW JERSEY

Picatinny Arsenal Technical Report 3098

DETONATION OF A CYLINDER OF HIGH EXPLOSIVE CONTAINING AN AXIAL CORE OF PYROTECHNIC COMPOSITION

by

J. Hershkowitz, Engineering Sciences Lab., FRL
E. Dalrymple, Explosives and Propellants Lab., FRL
D. Dorfman, Warheads and Special Projects Lab., AED

(Report prepared by J. Hershkowitz)

August 1963

Approved by: W R Benson
W. R. BENSON
Chief, Engineering Sciences
Laboratory

Feltman Research Laboratories
Picatinny Arsenal
Dover, N. J.

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ABSTRACT

In order to determine whether an explosive based on the complete combustion of aluminum within the detonation zone would be superior to existing explosives, observations were made of the detonation behavior of a composite, consisting of an outer cylindrical shell of 9404 explosive (OD = 1.5 inches, ID = 0.5 inch) and an inner cylindrical core of 60/40 potassium perchlorate/aluminum (OD = 0.5 inch). The explosive shell was in the form of two cylinder-halves. The 60/40 insert consisted of pressed pellets, of density 2.35 g/cm^3.

The observed profile propagation velocity was 7990 m/s. The detonation front at the cylindrical surface of the explosive was preceded by one in the residual space between the two explosive cylinder-halves. The front in the 60/40 and the front at the cylindrical surface of the explosive arrived at the end of the stick almost simultaneously. The luminosity of the 60/40 products was more intense and of much longer duration than that of the explosive products.

These experimental results showed the following: jet effects in the residual space between the cylinder-halves; the 60/40 detonation always propagating at a rate set by side initiation and compression by the 9404; the aluminum combustion completed as an afterburning process, rather than forward of the Chapman-Jouguet plane. Computer calculations of the ideal detonation velocity of the 60/40 predicted speeds of 6685 m/s and 7442 m/s for densities of 2.25 and 2.50 respectively. It was concluded that the 60/40 composition can not be made to provide an explosive superior to 9404.

INTRODUCTION

The experiments described in this report were undertaken to establish whether a superior explosive would result if a large fraction of the heat of formation of Al_2O_3 (condensed 400, gas 240 kilocal/mole at 298°k) could be released within the detonation zone (prior to Chapman-Jouguet plane) instead of in the usual afterburning process. To achieve this end, it was considered necessary to surround a core of high-density potassium perchlorate/aluminum mixture with a powerful high explosive, 9404, and initiate the latter so that as it propagated it would serve to further compress the core mixture during the onset of detonation and maintain strong confinement until the Chapman-Jouguet plane was reached. It was hoped that the resulting detonation of the core would then become self-sustaining and the observed propagation rate would exceed that of 9404 explosive. If this did occur, the core would then be initiating the 9404 instead of vice-versa and this would be deducible from the shape of the detonation front at the end of the composite cylinder.

EXPERIMENTS

Pellets 0.5 inch in diameter and approximately 3/8 inch high were made by pressing a potassium perchlorate/aluminum (60/40 by weight, 28/15 microns average particle size) mixture to a density of 2.35 g/cm^3. A cylindrical shell (OD = 1.5 inches, ID = 0.5 inch) for these pellets was made of composition 9404 explosive.

Because of the sensitivity of the pellets, it was considered hazardous to push them into the hole in the explosive. To circumvent this, two 9404 shells were cut so that two mating cylinder-halves were obtained. With these, the assembly operation could be done remotely, but unfortunately the junction of the explosive halves was not perfect, the residual space between them ranging from about 0.001 to 0.010 inch. A typical experimental item (including the simple lens system used for core compression) is shown schematically in Figure 1.

The propagation of the detonation was observed by both a Beckman-Whitley Model 189 Framing Camera and a Model 194 Streak Camera. The former camera viewed the side of the experimental item while the latter, by use of a mirror, viewed the end as well as the side. Results were obtained with the plane of the junction of the two explosive-halves differently oriented.

RESULTS

Figure 2 is a framing camera photograph taken perpendicular to the axis of the cylinder, with the camera axes in the mating plane of the

cylinder-halves. The luminosity in the region of the residual space between halves is obviously leading that of the rest of the explosive. No contribution from the 60/40 core is apparent.

In Figure 3, the mating plane has been rotated 45 degrees. The phenomenon described in the previous paragraph is apparent. The luminous front in the wider residual space arrives first at the end of the composite cylinder.

The mating plane of the cylinder-halves has been rotated 90 degrees for the sequence shown in Figure 4. The faster luminous front is associated with the residual space estimated to be 0.010 inch wide, the slower one with an estimated 0.001 inch width. The results shown in the previous two figures are thus reinforced.

A simultaneous streak photo of the experimental item of Figure 4 is shown in Figure 5. The camera slit coincided with the mating plane. The end of the item was viewed with a mirror, the side directly. This is shown by the section of the still photo added to the streak photo. Figure 6 is a schematic version of the previous figure. The subparagraph designations below refer to the letters in Figure 6.

a. Mirror view of end of composite cylinder. Inner circle is outer boundary of 60/40 (0.5 inch). Outer circle is boundary of 9404 (1.5 inch). Mating plane of cylinder-halves contains image of streak camera slit. The wider residual space faces the streak camera.

b. Direct view of side of composite.

c. Image of streak camera slit.

d. Time is increasing in the direction shown. Interval shown is one microsecond.

e. Luminous products moving outward from periphery of charge. Outer cutoff of luminosity is associated with end of mirror.

f. The image of the luminosity present within the wider (0.010 inch) residual space between the mating cylinder-halves is seen in the mirror at the end of the composite charge.

g. Luminosity within narrow (0.001 inch) residual space is not seen via mirror.

h. Luminosity front at wider residual space progresses toward end of charge at 7990 m/s.

i. Note short duration of strong luminosity at any one position.

j. Front in wide residual space arrives at end of stick.

k. Luminous products move toward axis of charge.

l. Front in narrow residual space arrives at end of stick and fans out in both directions. This reveals shape within residual space.

m. Detonation front within photoflash arrives at end of charge.

n. Strong luminosity of 60/40 is increasingly screened by luminous products from outer shell. As these decrease in intensity and the 60/40 continues to be highly luminous the afterburning of the 60/40 becomes evident.

o. Afterburning of aluminum in the 60/40 core. High luminosity results from presence of condensed species. These can be aluminum, either uncombusted or as a condensed product, or condensed Al_2O_3.

p. A decrease in the speed of the luminous products occurs when the end of the charge is reached. The products then move toward the mirror.

q. The increase in speed shown here is believed to be associated with the strongly luminous products of the 60/40 entering the space between the end charge and the mirror.

r. Here the products are impacting the mirror.

The experiments described in this report were proposed about 18 months ago, but the experimental items could not be assembled and evaluated until recently. This delay was due to a combination of handling safety problems that had to be surmounted and the low priority of this experiment. In the intervening period, a computer code was obtained from LRL (RUBY) and experience developed in its use on aluminized compositions (Ref. 1). The detonation behavior of the 60/40 mixture was calculated for densities of 2.25 and 2.50 g/cm^3 and the complete results are presented in Table 1. The predicted ideal detonation velocities are 6685 m/s and 7442 m/s, respectively.

DISCUSSION

In this section of the report, it is proposed to discuss the experimental and the computer results, and their significance with respect to the detonation of 60/40 potassium perchlorate/aluminum.

The residual space between the mating halves provides a volume in which explosive products are jetted in the forward direction (Munroe jet). These products also act on the adjacent explosive surfaces and initiate detonation. Figures 2, 3, and 4, particularly the latter, indicate that this detonation does not progress far around the cylindrical surface before the main detonation arrives. It was also found that as the profile advanced along the cylinder, the distance of that front associated with the residual space from that at the surface of the cylinder did not change significantly.

The lag of the front in the 60/40 behind that in the residual space, as shown in the streak photo, can be attributed to either an ignition delay in the 60/40, or to no initiation of the 60/40 by the Munroe jets because of the small contact surface with the 60/40 pellets. The front in the photoflash arrives at about the same time as that observed at the cylindrical surface of the explosive. This fact supports the idea that the 60/40 is initiated by the 9404 instead of by the Munroe jets.

In the streak photo, at ℓ in Figure 6, the front within the narrow residual space is most advanced about 1/3 of the way from the inner surface of the explosive, showing that the 60/40 is not initiating the explosive at the residual space.

There are two results which are independent of the presence of the residual space. These are the fact that once initiated the 60/40 did not propagate more rapidly than the 9404, and second that the 60/40 was highly luminous for a long period after initiation (afterburning).

The computer calculation indicates that ideal detonation velocity for the 60/40 in the achievable density range is less than that observed for the 9404 explosive and less than the ideal detonation velocity for the 9404. A reasonable explanation of the observed results,therefore, is that as the detonation at the inner cylindrical surface of the 9404 shell progresses forward, it initiates the 60/40 at each point. The 60/40 detonation spreads radially inward as in an overdriven explosive. The long-duration high luminosity of the 60/40 is due to the presence of condensed species in the products and further formation of such products in the rarefaction that ensues when the end of the composite is reached. Calculation of the isentrope shows this effect.

CONCLUSION

The experiments show that a pressed mixture of 60/40 potassium perchlorate/aluminum, when initiated by a surrounding 9404 explosive, does not exhibit a higher detonation velocity than the 9404. The 60/40 exhibits a long-duration luminosity, indicating "afterburning" is still occurring. Thus the concept of making a "superexplosive" by this means was unsuccessful. The computer calculations referred to in the previous paragraph, if available prior to the experiments, would have been interpreted as predicting this result. It follows that further studies of this type should be preceded by computer calculations for the mixtures involved and study of the numerical results in light of detonation theory.

ACKNOWLEDGEMENTS

This program was partially funded under the Subtle Lethal Mechanism program, which is a study currently being conducted by the Engineering Sciences Laboratory, FRL, for the Warheads and Special Projects Laboratory. Other funding used was from the Terminal Ballistics Detonation Kinematics project which is underway at the Engineering Sciences Laboratory, FRL, with Ballistic Research Laboratories, Terminal Ballistics Laboratory sponsorship.

REFERENCES

Hershkowitz, J., "The Combustion of a Granular Mixture of Potassium Perchlorate and Aluminum Considered as Either a Deflagration or a Detonation," Picatinny Arsenal Technical Report 3063, January 1963.

Table 1

Computed Ideal Detonation Parameters for 60/40 Potassium Perchlorate/Aluminum at Densities of 2.25 and 2.50 g/cm^3 (values at Chapman-Jouguet Plane)

Density, g/cm^3	2.25	2.50
Temperature, ^{o}K	6826	6935
Pressure, megabars	0.240	0.314
Detonation Speed, m/s	6685	7442
Specie concentration in moles per gram of explosive*		
Al	6.3 E-6	3.0 E-6
AlO	8.5 E-9	1.8 E-9
Al_2O	8.8 E-6	4.0 E-6
Al_2O_2	8.8 E-9	2.8 E-9
Al_2O_3	2.4 E-3	1.9 E-3
Al Cl_3	1.4 E-3	1.4 E-3
K	4.3 E-3	4.3 E-3
K_2	5.3 E-9	3.8 E-10
KCl	3.5 E-5	8.8 E-6
O_2	6.6 E-10	2.4 E-10
O	1.3 E-8	4.8 E-9
Al_2O_3 (condensed)	3.4 E-3	3.8 E-3
Al (condensed)	1.8 E-3	1.8 E-3

* E-6 means multiply by 10^{-6}

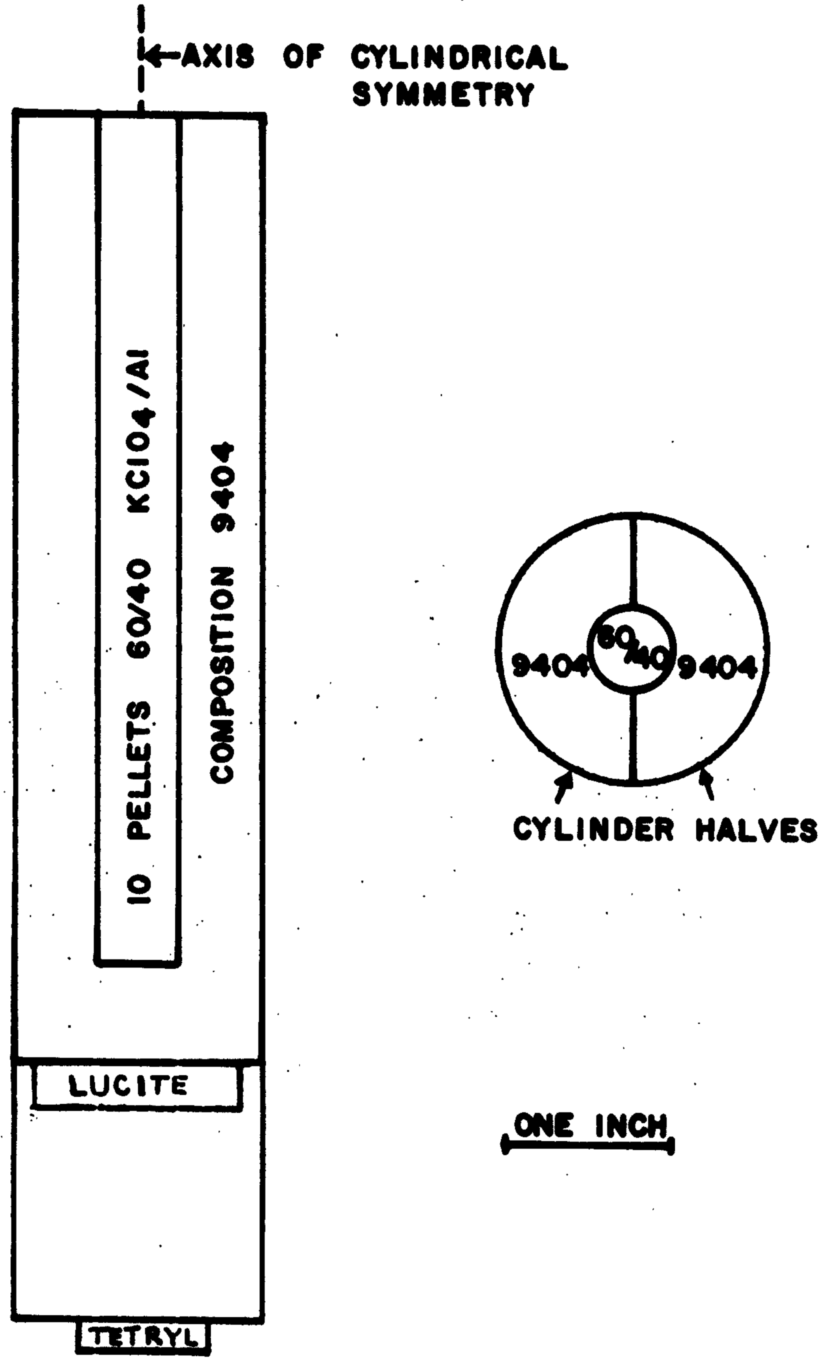

Fig 1 Cross sectional view of test item

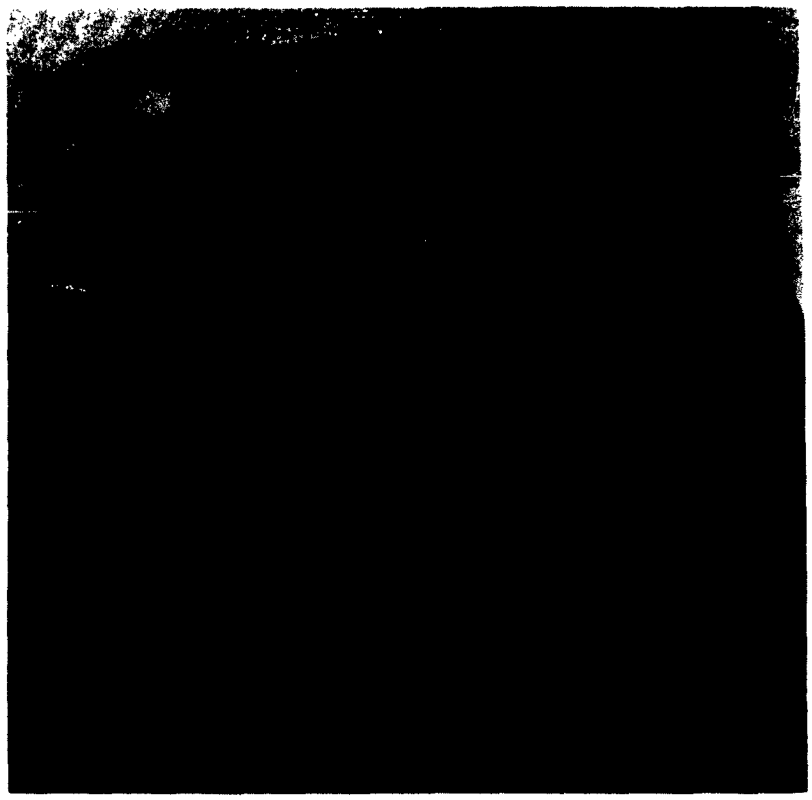

Fig 2 Photos parallel to plane between explosive halves

Fig 3 Photos at 45° to plane between explosive halves

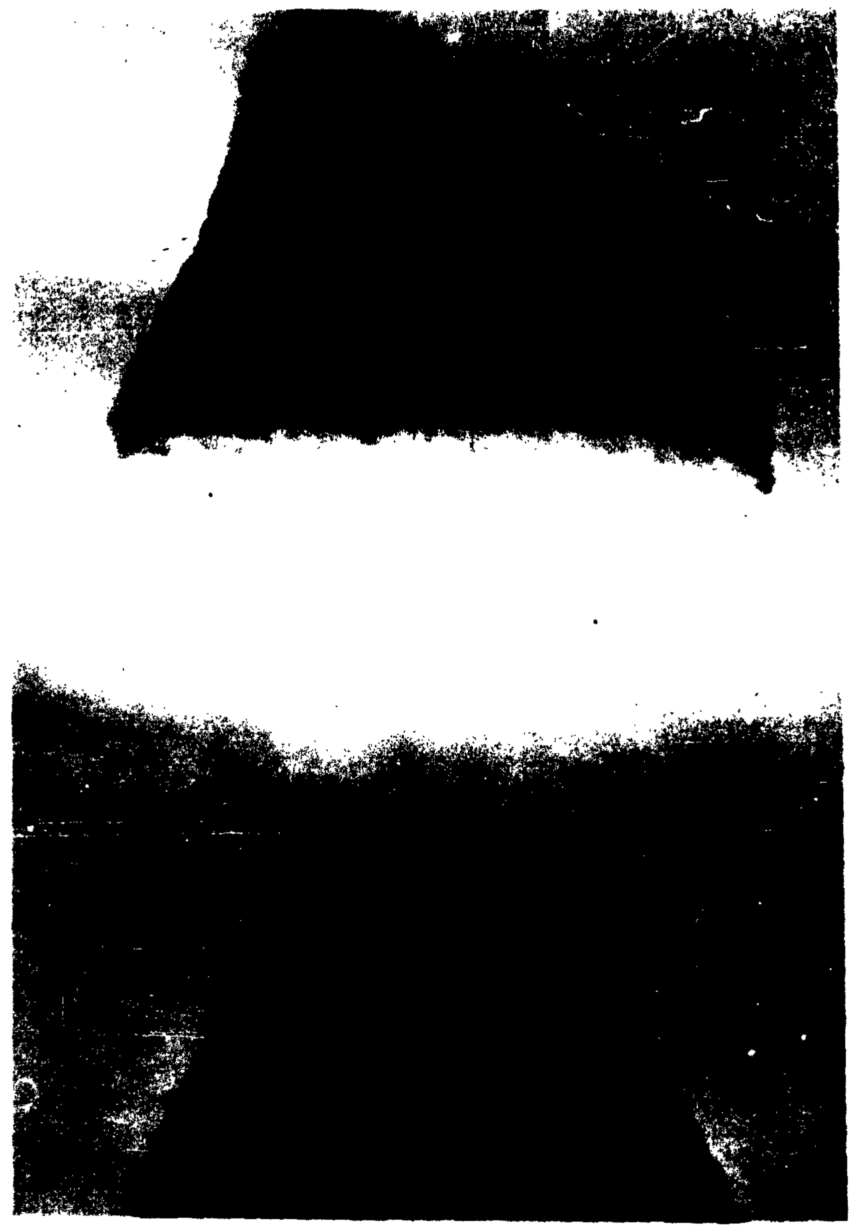

Fig 4 Photos perpendicular to plane between explosive halves

Fig 5 Streak photo parallel to plane between explosive halves

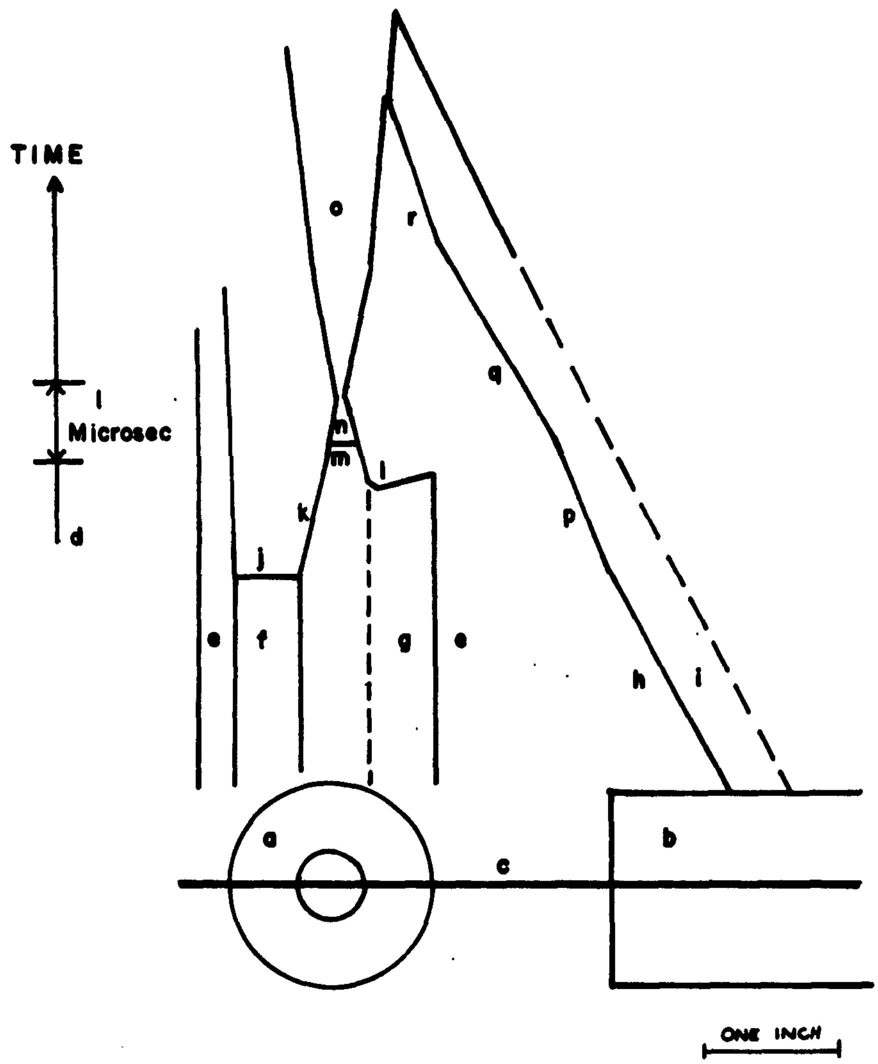

Fig 6 Interpretation of streak photo

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2. Pyrotechnics – Combustion

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III. Dorfman, D.
IV. Title
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Picatinny Arsenal Technical Report 3098, August 1963, 14 pp, table, figures. Unclassified Report

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